5. The red king crab (Paralithodes camschaticus) in the Barents Sea

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5.1 Summary

The red king crab is deliberately introduced and has spread to most parts of the southern Barents Sea, from about 36 ° E to about 26 ° E. It is found more off shore in Russian than in Norwegian waters. The biology of this crab is similar to what is found in native areas; hatching larvae and spawning takes place in shallow waters in spring, and the larvae stay pelagic up to 60 days before it settles. Growth is faster and maturation size larger in Norwegian waters than in native areas, whilst diet is the same. Main prey is different benthic organisms. This feeding behavior cause serious impact on receptive benthic communities in areas with high crab abundance.

In Norway, the red king crab management regime has two goals; to maintain a long term quota regulated fishery within a limited area, and to limit further spread of the crab beyond this area.

5.2 Introduction history

The red king crab was deliberately introduced to the Barents Sea by Russian scientists at several occasions during the 1960s and 1970s (Orlov and Ivanov 1977). The overall aim of the introduction was to create a new fishery on a new valuable fishing resource, and Russian and Norwegian scientists verified that the introduction was a "success" in a paper in 1995 (Kuzmin *et al*. 1996).

During the first years of appearance the red king crab was mainly regarded as a "blessing" for the fishing industry, both in Russia and in Norway. Only a few expressed any concerns about the crab being a non-

native species, posing threats to the receptive ecosystem. This opinion of the crab, however, changed sometime just after the new millennium, particularly in Norway. The new apprehension has affected also the way this species is managed in Norway, but seems to have had no impact on the king crab management in Russia.

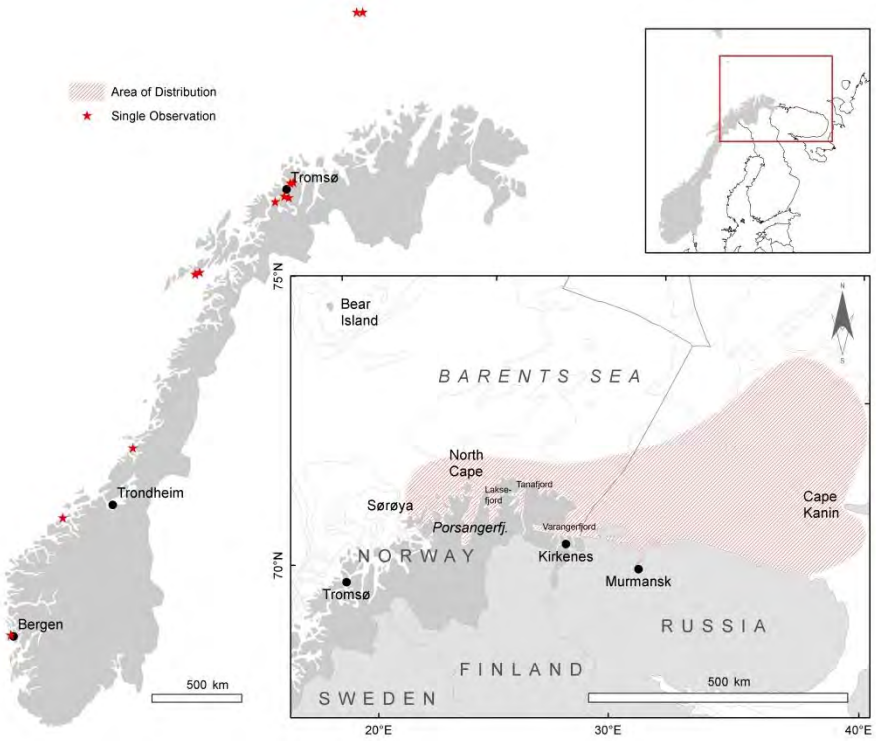
5.3 Biology of the red king crab

5.3.1 Spread and abundance

Red king crabs were recorded for the first time in Norwegian waters in 1977, but it was not until the beginning of the 1990s that they became abundant in limited areas close to the Russian border (Nilssen 2003). At that time the crab had occupied most of coastal areas on the Kola peninsula from about 36° E to the Norwegian border. In Norwegian waters the crab spread continuously westwards within near coastal waters. The spreading appeared to be more or less discontinuous in the way that small aggregations of crabs popped up at small localities in inner part of fjords further west, with no recordings in the areas back to the source population.

It is difficult to locate the front of the king crab distribution in Norwegian waters today, but we assume that the crab has moved by itself at least to areas around Tromsø in west, and to distances of about 12–15 nm off shore (Figure 1).

Figure 1: Approximate distribution of the red king crab in the Barents Sea. Red asterisks indicate catch sites of single crabs



The current Norwegian management system (see page 58) results in a low population density and consequently a limited spreading rate west of 26° E. There are very few observations of red king crabs far off shore in the Norwegian part of the Barents Sea, while the crab seem to disperse more into open sea waters in the Russian part. Here, the highest densities are found some 30–50 nm ashore where the largest fishery harvest is also taking place (Figure 1).

There were no estimates of the total stock indices in Norwegian waters until 2002. Therefore, legal male stock indices could be regarded as a proxy for the total stock. As the crab spread to new areas further west, the population was followed up with stock estimates in new areas continuously. Therefore, the presented stock indexes of legal male crabs for the first period were only for Varangerfjorden; followed by Tanafjorden and the area Østhavet in 2003, and Laksefjorden in 2004 (Figure 1). The complete crab stock in the Norwegian commercial area (see pages 56–7) was estimated for the first time in 2008.

5.3.2 Demography

As the general picture of unexploited accumulated fish stocks, the first catches of red king crabs in newly established areas in Finnmark were characterized by the presence of many large individuals of both sexes. Abundant year classes, visualized as peaks in the annual size distribution were also commonly observed during the "virgin" period before the exploitation rate increased largely after about 2000. Juvenile crabs, smaller than about 50 mm carapace length, are sparsely represented in our samples all years, due to the crab life history. Juvenile crabs inhabit shallow areas all year around, and start descending to deeper areas as they increase in size. Therefore, it is not possible to establish reliable stock indices of this part of the crab stock.

After the introduction of a high exploitation rate in the Norwegian red king crab fishery, it seems that abundant year classes appear less frequently, and that recruitment has become more stable at a low level.

5.3.3 Growth and reproduction

Growth in the red king crab, as in all crustaceans, consists of two parameters; size increment at each molt, and the frequency of molting. Female red king crabs always molt before spawning of eggs, while molting in adult male crabs is more irregular (McCaughran and Powell 1977). Juvenile red king crabs may molt on several occasions during a year and the molting frequency becomes once a year as they grow to mature specimens (Donaldson and Byersdorfer 2005). The red king crab in Norwegian waters seems to grow somewhat faster than crabs in their native areas, but this may have changed in recent years due to less available food (Nilssen and Sundet 2006, Oug *et al*. 2011).

Size at maturity for both male and female red king crabs seems to be about 110 mm carapace length (Rafter *et al*. 1996, Hjelset *et al*. 2009). This is larger than in the red king crabs native areas. Hatching, spawning and mating takes place at shallow waters (< 20 m) in spring where high numbers of male and female crabs aggregate for 2–3 months (Powell and Nickerson 1965).

Each mature female crab spawns commonly 100–300 thousand eggs every year which are fertilized, dependent on crab size (Hjelset *et al*. 2012), and an average female performs approximately 10–15 spawning seasons. This means that the red king crab as a species has a very high reproductive potential, which may be one of its major success factors regarding the adaptation to the new ecosystem in the Barents Sea. There is, however, observed a significant reduction in the potential egg produc-

tion in the Norwegian red king crab stock in recent years, probably due to the fishery on large males only (Hjelset 2014).

The larval phase in the red king crab life history may be of crucial importance when assessing spread of the species. The crab larvae may be pelagic for up to 60 days, dependent on environmental temperature, and may therefore be spread by currents (Pedersen *et al*. 2006). Unpublished results also show that the red king crab larvae are able to survive higher temperatures than earlier anticipated (Sparboe unpubl.). This may indicate that the crab could spread to a wider area in the northeast Atlantic in the future.

5.3.4 Diet and feeding

Several studies show that the red king crab feed on numerous prey categories, both in its native areas as well in the Barents Sea (Feder and Jewett 1981, Sundet *et al*. 2000). These finding may lead to the conclusion that the crab is a generalist feeder (Falk-Petersen *et al*. 2011), but other studies reveal that the crab prefers and remove large individuals of invertebrates such as bivalves, echinoderms and siphunculids (Haugan 2004, Oug *et al*. 2011). Prey preference studies based on stomach content analysis may, however, be difficult to interpret since for some prey groups only soft parts of the animals are ingested (e.g. large mussels), while for other groups (small mussels and worms) hard parts enter the digestive system (Jørgensen 2005, Jørgensen and Primicerio 2007). This entails that the presence of some prey groups in the diet may be overestimated.

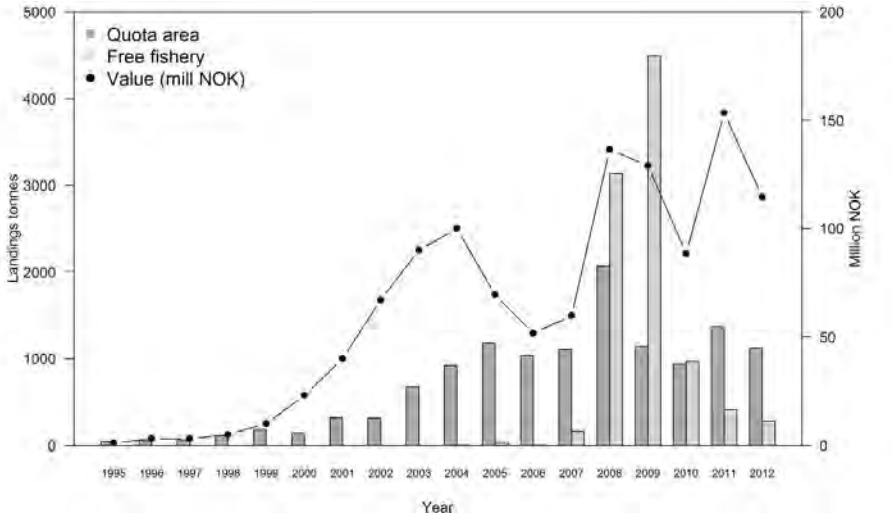
5.3.5 Fishery

The major fishery for the red king crab has taken place in the Bering Sea and the northern Pacific, where the exploitation of the crab can be dated back to 1930 (Otto 1986). The fishery in this part of the world is mainly carried out by the USA, Russia and Japan, where the US annual maximum catches amounted to about 65 thousand tons in 1980 (Otto op cit). Since then the catches have gone down dramatically, and the fishery in Alaskan water closed for several seasons during the 1980s and 1990s. Total catch in recent years has been 3–10 thousand tons in Alaskan waters.

The red king crab fishery in the Barents Sea started as a small experimental fishery agreed upon by Norway and Russia in 1994. This fishery lasted as an experimental fishery in Norway until 2002 and in Russia until 2004, when they were transformed to more regular commercial

fisheries. The catch quotas were small in both countries during the first years, but increased significantly at the onset of the commercial fishery (Figure 2). The annual value of the total landings of red king crab has varied greatly; this is mostly due to varying market prices (Figure 2).

Figure 2: Landings of red king crab in quota regulated area and free fishing area in the Norwegian coastal waters off Finnmark



Stippled line show value of annual landings in million NOK.

Only pots are allowed in the red king crab fishery both in Russia and in Norway, although the crab fishery is very different in the two economic zones. In Russia the red king crab fishery is performed by large (> 60 m) vessels operating many pots, whilst in Norway this fishery is reserved for small vessels operating only a few (<30) pots in near coastal waters. In Norway, only those fishermen experiencing bycatch problems with the red king crab in other fisheries (gillnet, long line etc) are given license and annual catch quotas. This entails that the majority of the fishers catching the red king crab in Norway lives in Finnmark County, due to the distribution pattern of the crab.

5.4 Impact on ecosystem and fisheries

Early studies on the red king crab stomach content indicate that this species could affect the benthic ecosystem since the majority of the prey organisms were benthic living species (Sundet *et al*. 2000). Revealing any such impacts was however, challenging due to lack of knowledge of

the recipient benthic ecosystem before the red king crab appeared in high abundance in Norwegian waters. The lack of "pre-introduction" base line studies of the benthic fauna may be explained by the low focus on introduced species among leading scientists at that time in Norway. Fortunately, a study of the benthic fauna with a different goal, carried out in Varangerfjord in the mid 1990s, came to our knowledge and could work as a comparable study of the impact of the red king crab. Benthic sampling stations from the early 1990s were re-sampled in 2007 and revealed serious changes in the benthic ecosystems where the red king crab have been present in high densities for a long period (Oug *et al*. 2011). The major changes caused by the crab were a significant reduction in both number of species, standing biomass and that all large specimens of bivalves, echinoderms and polychaetes were absent. In addition there were indications of a reduction in bottom sediment quality due to the feeding activity of the crab.

The impact of the red king crab on the local fishery activity was obvious as soon as the red king crab entered Norwegian waters in some amount. The crab caused problems by entangling gillnets and by removing bait from long-lines (Sundet and Hjelset 2002).

5.5 Management

The red king crab occupied a particular role in the Barents Sea fauna when it appeared in high abundances in the early 1990s. Before this time, there was no crab species that abundant, and in addition being a valuable fishing resource. The consciousness among marine scientists and fishery managers about non-native species was also low in these early years. Therefore, the red king crab was mainly regarded as a valuable species for fishery during the first years. It was much later (around 2000) recognized as an unwanted species as well, and these attitudes also mirrored the management actions been taken. During the experimental fishery period the red king crab was regarded as a shared stock between Norway and Russia, and the annual quotas were set by the Mixed Norwegian-Russian Fishery Commission. The management in this period was mainly based upon a 3-S regime (Size, Sex and Season), in addition to depth limitation for fishing activities. The exploitation rate was low during this period allowing the red king crab stock to increase and spread to new areas. This period of joint management with Russia lasted until 2007, when the Commission agreed on a separate national management. In Norway, the Ministry of Fisheries and Coastal affairs

launched a whitepaper to the Parliament where official management goals were presented for the first time (Anon 2007). At that time one was aware that this new species also had some devastating effects on the recipient ecosystem as well as the performance of local gill net fishery. The main aim of the Norwegian red king crab management was therefore to stop the spread of the crab beyond a limited area (the quota regulated area) in eastern Finnmark, east of 26° E (Figure 1), where the crab should be commercially harvested with a long term revenue goal. To limit further spread, a non legislated free fishery was introduced in areas outside the quota regulated area, including a ban on releasing viable crabs back to sea. The main management tools within the quota regulated area today are a minimum legal size (130 mm carapace length) for catch on males and females, trap limitation and vessel quotas.

The applied management of the red king crab in Norwegian waters seems to be successful regarding limiting the spread of the crab, and keeping the stock low in areas outside the quota regulated area. Keeping an area of long term exploitation, maintains also an economical way of getting rid of all red king crabs caught in Norwegian waters. However, the high densities of crabs inside the quota regulated area have obvious consequences for the benthic fauna since the crab feeding activities both reduce the biomass as well as the species composition of the benthic communities. The long term consequences of these changes are unknown and we fear that maintaining this pressure on the benthic ecosystems may result in a permanent change.

5.6 The snow crab (*Chionoecetes opilio*) in the Barents Sea: Summary

This crab is not deliberately introduced and appeared in the Barents Sea for the first time in 1996. Since then, it has spread to most of the northern areas of the Russian zone and into international waters, the Norwegian zone and Svalbard waters. Little is yet known of the biology of this crab in the Barents Sea, but preliminary studies indicate strong similarities with what is found in native areas. It is expected that the snow crab will occupy most parts of the northern Barents Sea including all Svalbard waters. We also anticipate that this crab may cause serious effects on the benthic fauna within its distribution area. Fishery for the snow crab in the Barents Sea started in 2013, and management plans for this species is expected to be launched during 2014, both for the Russian and the Norwegian zone.

5.6.1 Appearance and origin

In 1996 five snow crabs were caught in the slope areas on the Goose Bank in the Barents Sea by Russian scientist. This was the first recording ever of this species in the North-eastern Atlantic. The natural distribution of the crab is in the Bering Sea, coastal eastern Canada and along the western coast of Greenland. Several hypotheses on the origin of this introduction are proposed. The crab is likely either from the eastern areas or from western Atlantic. In addition, it is also possible that the crab might have moved by itself from the Chukchi Sea in eastern Russia, since examples of the crab have been found both in the East Siberian Sea as well in the Laptev Sea. Genetic analyses are under way which hopefully will reveal the answer to this question.

5.6.2 Biology and life history

The knowledge on the biology and life history of the snow crab reveals area specific differences. There seem to exist, however, some common features given below.

Unlike the red king crab the snow crab has a terminal molt as the crab become mature. Female snow crab may be between 30–95 mm carapace width at the terminal most, whilst the sizes of males may vary between 40 and 150 mm in Atlantic Canada. The crab lives a maximum of five years after the terminal molt (Conan and Comeau 1986, Hartnoll *et al*. 1993).

Female crabs hatch the old eggs just prior to spawning in the spring. New egg clutches may count between 20 and 150 thousand eggs which are carried under the female abdomen for almost a year (Moriyasu 2011). There are some indications that crabs facing harsh (temperature) conditions may spawn every second year, but annual reproduction period is the common situation (Moriyasu and Lanteigne 1998).

The snow crab larvae drift in the upper sea water column for up to two months and in contrast to the red king crab they do not necessarily settle in shallow areas, but may well be found in deeper (> 200 m) parts of the sea. Juveniles seem however to be more restricted to low temperatures than adult crabs (-1–3^{o} C), which probably will be a bottleneck for where the snow crab will spread in the Barents Sea (Dionne *et al*. 2003).

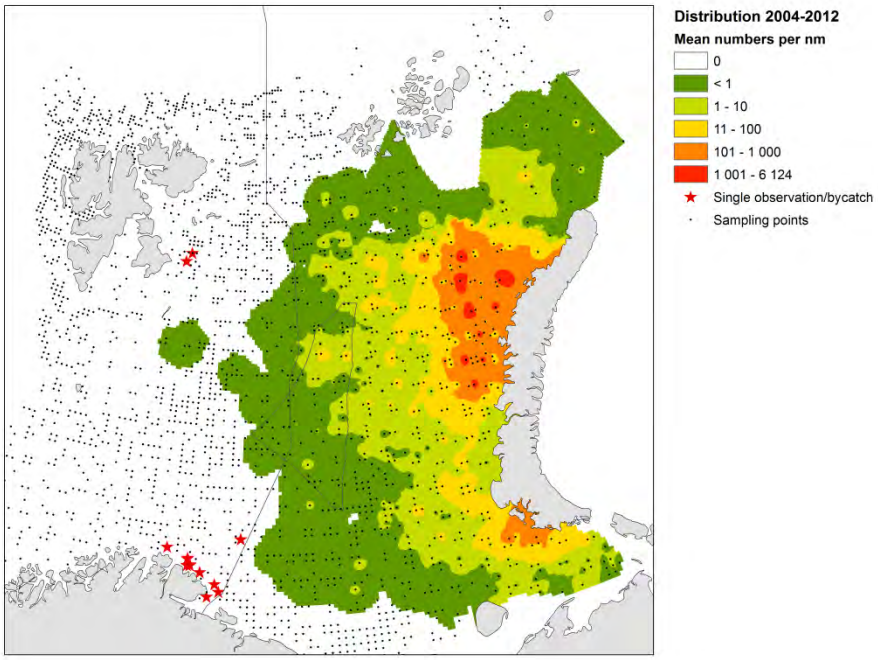
Several numbers of prey groups are found in the diet of the snow crab in the Barents Sea based on stomach analysis (Sundet unpubl.), but species groups such as Polychaeta, mussels and Echinoderms are dominating in the stomachs. This means that we may expect that the snow crab can have effects on major parts of the benthic species communities.

The growth rate of the snow crab may vary, but it is believed that the crab is about 5–6 years old at the terminal molt, and that maximum longevity is about 15 years.

5.6.3 Distribution in the Barents Sea

Since the first recordings of the snow crab in the Barents Sea, the crab has rapidly spread to most parts of the northern Russian Economic Zone and northwestwards into international waters, then Norwegian Economic Zone and the Svalbard Protection Zone (figure 3). There are also findings of single crab specimens along the coast of Finnmark and as far northwest as Olgastredet between King Carls Land and Edge Island. Due to its known temperature preferences it could be expected that the snow crab will continue to spread further north and west in the Barents Sea; most likely will the crab be found around the whole Svalbard and Franz Josef archipelago in the future.

Figure 3: Distribution and density of snow crab in the Barents Sea based on by-catches in bottom trawl during the IMR/PINRO ecosystem survey 2004–2012



Red asterisks indicate catch sites of single snow crabs

5.6.4 Management

So far there is no management regime for the snow crab in the Barents Sea implemented, neither in the Norwegian nor in the Russian zone, but both countries authorities have announced that they aim to implement management systems for the snow crab during 2014.

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